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(54) Title: MIXING PROCESS FOR MIXING OF MEDIA AS WELL AS DEVICE FOR CONDUCTING THE PROCESS

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The invention concerns a mixing process for the mixing of [different] media, at least one of which can flow easily. Simultaneously, the invention concerns a device for conducting the process.

The invention concerns a so-called static mixing device, i.e., a device without moving mechanical parts. Known mixing devices of this type, which operate, e.g. on the principle of dividing the flow and recombinating it at staggered sites, or, as, e.g., combustion chambers with spiral currents, are relatively greatly extended in the direction of flow and/or have a high pressure loss.

The invention has the goal of creating a mixing process and a device, which permits a homogeneous mixing of the media with as small as possible a pressure loss on a short flow path.

The mixing process according to the invention, by which this objective is achieved, is characterized by the fact that the easily flowing medium is conducted through a channel with an abrupt change [widening] of cross section, at which there occurs a detachment of the flow from the wall of the channel, and that the medium to be intermixed is introduced into the channel at the latest into the turbulence region that forms at the widening place.

The device for conducting the process according to the invention is characterized by a flow channel for the easily flowing medium, which has an abrupt change in the flow cross section, at which the flow detaches from the wall of the channel, as well as by an introduction opening for introducing the medium to be intermixed in the flow channel, which is found at a site that lies at the latest

in the turbulence region of the [cross-sectional] change, considered in the direction of flow of the easily flowing medium.

The present process and device for conducting the process is derived from the knowledge that the velocity profile in the channel is equilibrated almost ideally a certain extent after an abrupt widening of the cross section of a flow channel. A practically constant velocity is formed in the entire cross section of the flow channel with only a thin interface. An investigation of the flow shows that the turbulence of the flow is very great. The high degree of turbulence of the flow and the equilibrated velocity profile have a strong exchange motion crosswise to the direction of flow. This intensive exchange motion is utilized according to the invention for the intermixing of media.

Therefore, only the first medium needs to be easily flowable, whereby it may be a gas or a liquid. The medium to be intermixed may also be liquid or gaseous. However, it may also have the form of droplets or solid particles in a carrier gas or droplets or solid particles in a carrier liquid.

Thus, mixing processes for viscous media such as thick oils, pastes, etc. are not taken into consideration.

The invention will be explained on the basis of examples of embodiment shown schematically in the drawing. Here:

Fig. 1 shows a section through a mixing device according to the invention with diagrams drawn in of the course of the flow velocity and the concentration of the media over the cross section;

Fig. 2 shows a device with a serial connection of two widening parts;

Fig. 3 shows a mixing device with a diaphragm [aperture];

Fig. 4 shows a mixing device with a nozzle;

Fig. 5 shows a diagram of a device with a widening formed by a conical surface, whereby several introduction openings are found in the surface;

Fig. 6 shows a device with an introduction tube, which is found, in contrast to Fig. 1, after the widening part, and is directed counter to the flow of the easily flowable first medium;

Fig. 7 shows a device with several mixing channels in a larger channel;

Fig. 8 shows a view of the device from Fig. 7, considered in the direction of arrow P; and

Fig. 9 shows another form of embodiment of the device from Fig. 7.

Fig. 1 shows a mixing device with a flow channel 1, which has a segment 2 with smaller cross section and a segment 3 with larger cross section. An abrupt widening part 4 is found between segments 2 and 3, and this part is formed by an annular surface, which stands perpendicular to axis A of the channel and thus also to the direction of flow S of the easily flowable medium. The inner periphery of annular surface 5 is bounded by a sharp edge 6, and the outer periphery also forms a sharp-edged fluted groove 7.

An introduction tube 8 is introduced into segment 2 with smaller cross section, which [tube 8] has an output opening 10, which is directed downstream relative to flow direction S.

In operation, the easily flowable first medium flows through channel 1 in the direction of arrow S. After the abrupt widening part 4, a dead zone 11 is

formed, which has as a consequence the formation of a turbulence region with a high degree of turbulence after the widening part. In the turbulent flow, which is characterized by an equilibration of the velocity profile in the entire cross section of segment 3, a strong exchange motion exists in the crosswise direction to axis A of the channel, which is utilized for intermixing [the media] according to the invention.

The medium to be intermixed, which, as mentioned, may be a liquid, a gas, an aerosol, an emulsion, a dust in carrier gas or a suspension, is introduced through tube 8 and enters through opening 10 into segment 2 of channel 1.

The velocity courses of the individual media over the cross section of the channel are depicted in Fig. 1. Diagram I shows the velocity course of the first medium in segment 2 in front of widening part 4. The velocity course has a relatively broad interface at its edge. Diagram II shows the concentration profile of the medium to be intermixed right after introduction opening 10. As can be seen from the diagram, the flow of this medium runs only in a small part of the cross section.

Diagram III shows the velocity and thus the distribution of the first medium over the cross section in the turbulence zone after widening part 4. The diagram shows that the velocity is very much equilibrated over the entire cross section in the direction of axis A of channel 1, and that only a very narrow interface is present. Finally, diagram IV shows the concentration profile and thus the distribution of the intermixed medium over the cross section. It is seen that at the

given distance, the intermixed medium is distributed uniformly over the cross section.

Experiments have shown that the velocity course according to diagram III is reached at a place, which is removed from the widening part by four to five times the maximum diameter of the channel in the crosswise direction. In round channels, this dimension is diameter D (Fig. 1). Theoretically, the introduction of the medium to be intermixed is in this region, and it is also possible, since the turbulence current provides for the intermixing. In order to obtain a short channel, however, one practically need not go beyond 2D.

Fig. 2 shows a form of embodiment of the mixing device, in which a segment 3' is subsequently connected onto segment 3 of the channel, and this segment is found after a widening part 4'. The introduction of the medium to be intermixed is produced in this case through lines 8 and 8' with openings 10 and 10'. The openings are found just after widening parts 4 and 4', so that the medium to be intermixed reaches each time into turbulence region 11 or 11'.

The same medium can be introduced through introduction channels 8 and 8', so that the flow of the first medium is enriched by steps. However, different media can also be introduced through the two channels 8 and 8'.

Fig. 3 shows a simple form of embodiment of the invention, in which a diaphragm 20 is arranged in a channel 1. The diaphragm contains a sharp-edged diaphragm opening 21, which is arranged ecentrically according to the representation relative to axis A of the channel. At the place where dead zone 11 has its greatest extension, opening 10 of introduction channel 8 is found. The

mode of operation is otherwise the same as in the forms of embodiment according to Figs. 1 and 2.

The form of embodiment according to Fig. 4 is different from that of Fig. 3 in that the constriction in channel 1 is formed by a nozzle 30. Nozzle 30 has a nozzle opening 31 with a rounded front edge 32 and a sharp rear edge 33. In the segment of channel 1 found in front of nozzle 30, openings 8 of several introduction channels 10 are found.

The form of embodiment according to Fig. 4 has the advantage relative to that of Fig. 3 that the flow resistance of the device is smaller. The rounded edges 32 permit a constriction of the flow cross section and an increase of the flow velocity with smaller losses than is possible for the sharp-edged nozzle 20 according to Fig. 3.

In the form of embodiment according to Fig. 5, the widening part is formed by an oblique surface 40, which is conical in the present case, and which stands at an angle α to axis A of channel 1. Angle α must be larger that 30° in order to obtain a good rejection of the flow in most cases.

In the form of embodiment according to Fig. 5, the introduction of the medium to be intermixed or of the media to be intermixed is made through openings 10, which are found in surface 40.

The form of embodiment according to Fig. 6 is distinguished from that according to Fig. 1 by the fact that the flow of the medium to be intermixed runs from opening 10 counter to flow direction S of the first medium. The course of the flow of the medium to be intermixed is indicated by arrows M in Fig. 6. A

better intermixing and a shorter segment than in the other forms of embodiment can be obtained under certain circumstances for certain types of media, such as, e.g., dust-form media or for suspensions of heavy particles, by the arrangement of introduction opening 10 in counter-direction to flow S of the medium.

Figs. 7 and 8 show a mixing device, in which a larger flow channel 70 is divided by separating walls 71 into a multiple number of mixing channels 1. Nozzles 72, which form widening parts 4 by their sharp-edged ends are found on the input sides of channels 1. In order to introduce the medium to be intermixed, an introduction tube 73 is provided, which has lateral pieces with introduction openings 10. Introduction openings 10 are, as in the form of embodiment according to Fig. 1, directed in flow direction S of the first medium.

In this form of embodiment, a uniform distribution of the medium to be intermixed is achieved over a particularly short segment. The medium to be intermixed is simultaneously introduced, as shown, at nine places distributed uniformly over the cross section of channel 70. Since the length L of mixing channel 1 will be somewhat greater than four times its dimension D in the crosswise direction to the direction of flow S of the first medium, there results for the mixing process an essentially shorter length L than if a single nozzle according to Fig. 4 were to be introduced in channel 70.

The form of embodiment according to Fig. 9 differs from that of Figs. 7 and 8 only by the fact that the introduction of the medium to be intermixed is made through introduction openings 10, which are found in the walls of nozzle channels 74 of nozzles 72. The introduction of the medium to be intermixed is made into

introduction openings 10 through a channel 75, which is guided to the outside in a way that is not shown.

PATENT CLAIMS

I. Mixing process for the mixing of [different] media, one of which at least is an easily flowing medium, characterized in that the easily flowable medium is conducted through a channel with an abrupt change in cross section, at which the flow is rejected from the wall of the channel, and that the medium to be intermixed is introduced into the channel at the latest into the turbulence region that forms at the widening part.

II. Device for conducting the process according to patent claim I, characterized by a flow channel (1) for the easily flowable medium, which has an abrupt change (4) of the flow cross section, at which the flow is rejected from the wall of the channel, as well as by an introduction opening (10) for introducing the medium to be intermixed into flow channel (1), which is found at a place that lies, at the latest, in the turbulence region of modified part (4), considered in the flow direction (S) of the easily flowable medium.

SUBCLAIMS

1. Device according to patent claim II, further characterized in that introduction opening (10) for the medium to be intermixed is found upstream of modified part (4) in part (2) of channel (1) with smaller cross section (Fig.1).

2. Device according to patent claim II, further characterized in that introduction opening (10) is found after modified part (4), considered in the flow direction (S) (Fig.2).

3. Device according to patent claim II, further characterized in that modified part (4) has at least one sharp edge (6) at its inner boundary.

4. Device according to patent claim II, further characterized in that the modified part is formed by a surface (5) perpendicular to the longitudinal direction (A) of channel (1).

5. Device according to patent claim II, further characterized in that the modified part is formed by a surface (40) oblique to the longitudinal direction of channel (1), whose angle of inclination (α) to axis (A) of the channel is larger than 30°.

6. Device according to patent claim II, further characterized in that channel (1) has several abrupt changed parts (4, 4'), which are arranged one behind the other in the direction of flow (S) of the easily flowable medium.

7. Device according to subclaim 6, further characterized in that an introduction opening (10) for a medium to be intermixed is assigned to each abrupt changed part (4,4') (Fig.2).

8. Device according to patent claim II, further characterized in that the changed part is found at the end of a nozzle-type constriction (30, 72) of channel (1).

9. Device according to subclaim 8, further characterized in that a larger channel (70) is subdivided by separating walls (71) into a multiple number of

mixing channels (1), at whose input sides are found nozzles (72), which form at their ends the changed parts of the individual mixing channels (1), whereby an introduction opening (10) for a medium to be intermixed is assigned to each nozzle (72) (Figs. 7-9).

10. Device according to patent claim II, further characterized in that introduction opening (10) is distanced from changed part (4)* by double the maximum diameter (D) in the crosswise direction of channel segment (3) found after widened part (4).

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* The right-hand margin of column 6 is somewhat illegible—Trans. note.

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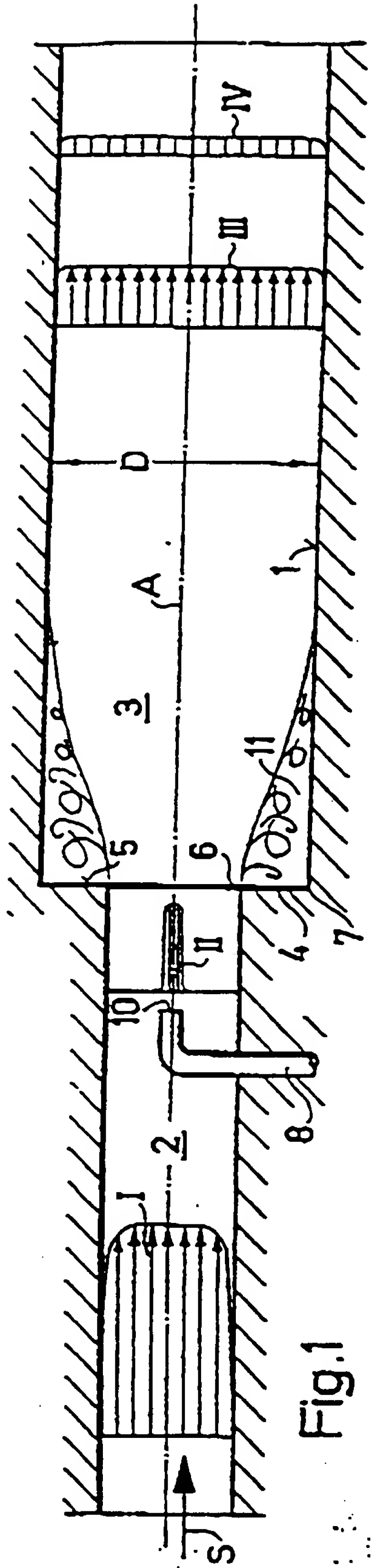

Fig.1

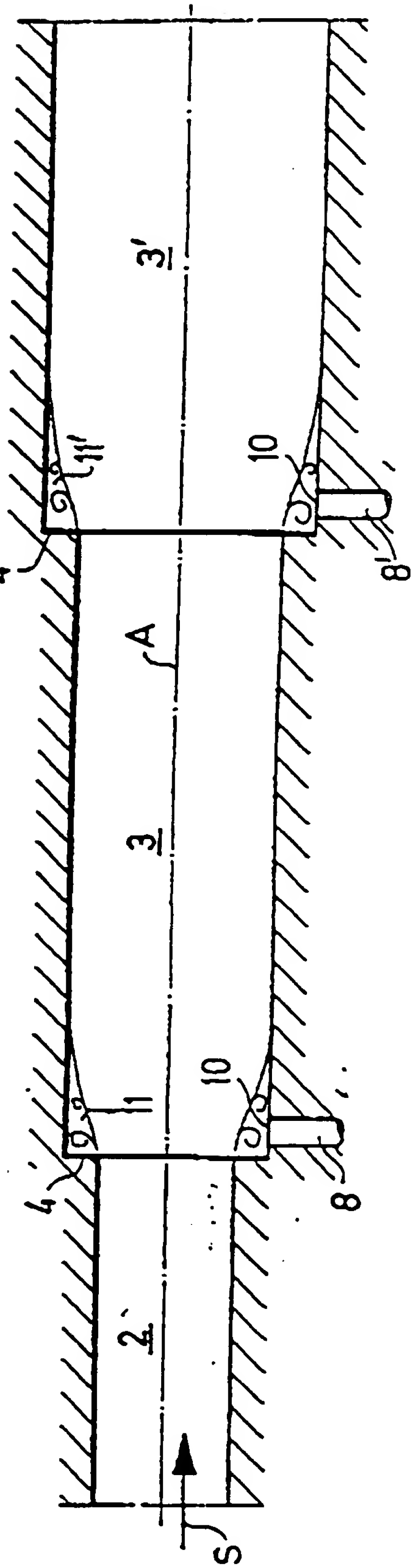

Fig.2

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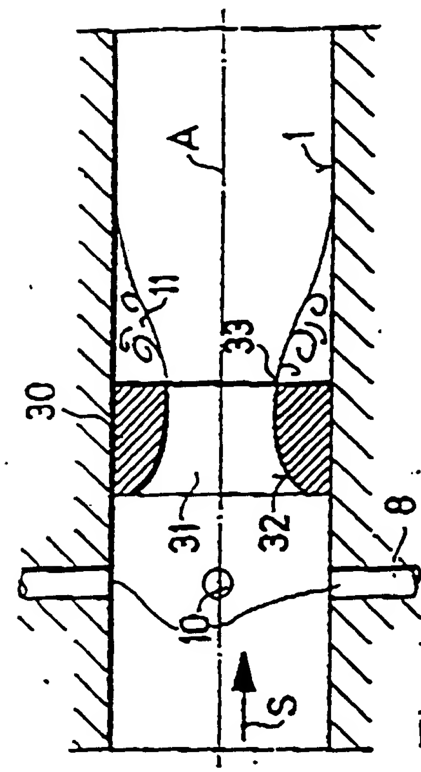

Fig.4

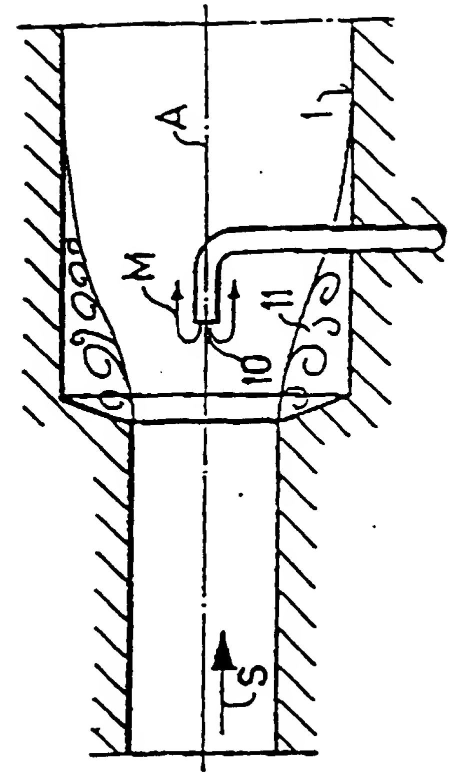

Fig.6

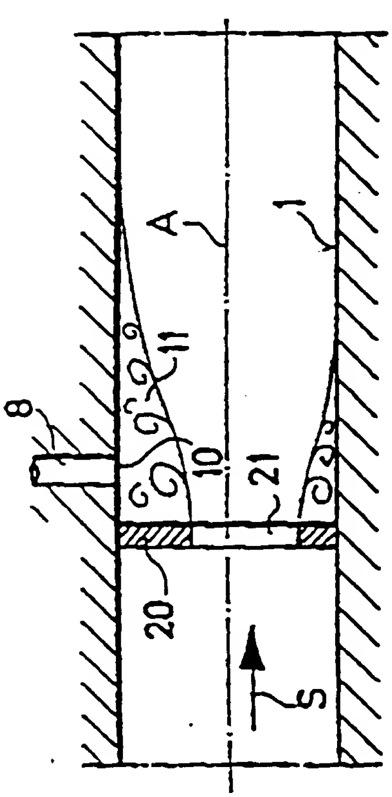

Fig.3

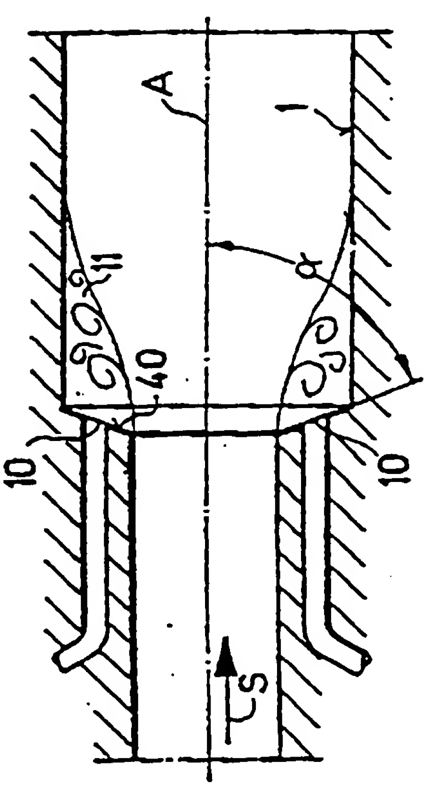

Fig.5

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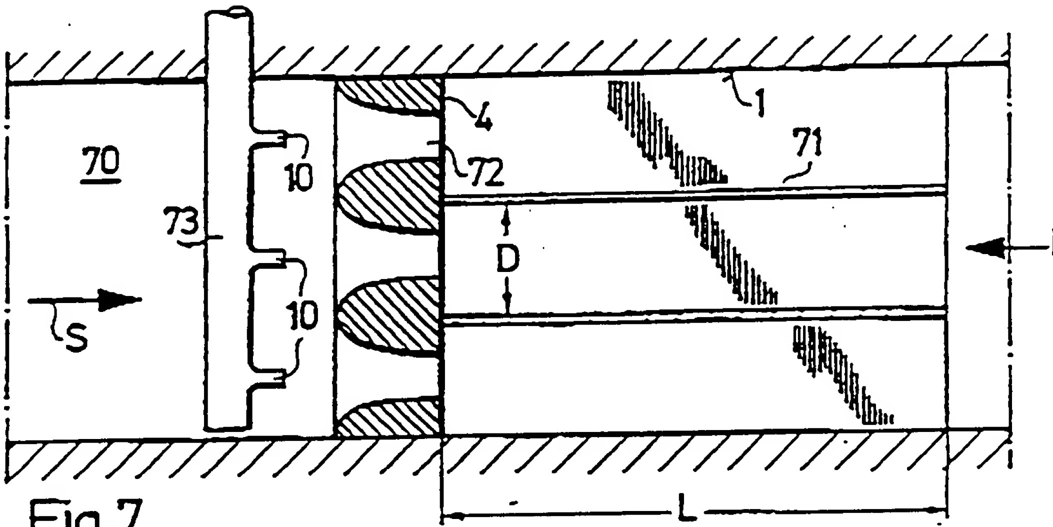

Fig.7

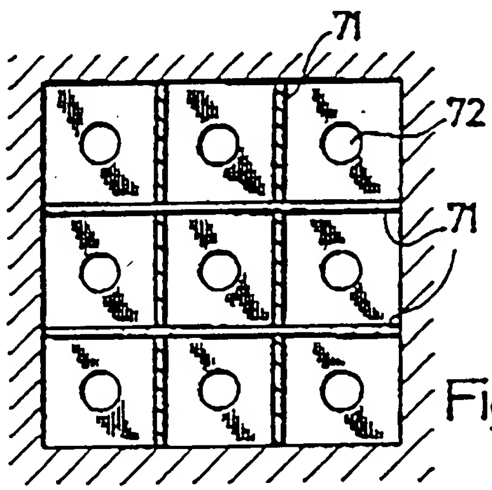

Fig.8

Fig.9